An innovative approach to predict the growth in intensive poultry farming

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Abstract

Chicken weight provides information about growth and feed conversion of the flock in order to identify deviations from the expected homogeneous growth trend of the birds. This paper proposes a novel method to automatically measure the growth rate of broiler chickens by sound analysis.

Through the application of process engineering, Precision Livestock Farming (PLF) can combine audio and video information into on-line automated tools that can be used to control, monitor and model the behaviour, health and production of animals and their biological response.

The aim of this study was to record and analyse broiler vocalisations under normal farm conditions, to identify the relation between animal sounds and growth trend. Recordings were made at regular intervals, during the entire life of birds, in order to evaluate the variation of frequency and bandwidth of the sounds emitted by the animals.

Two experimental trials were carried out in an indoor reared broiler farm; the audio recording procedures lasted for 38 days. The recordings were made, in an automated, non-invasive and non-intrusive way and without disturbing the animals in to the broiler house. Once a week, 50 birds were selected at random and their weight recorded in order to follow the growth trend in the birds.

Sound recordings were manually analysed and labelled using the Adobe Audition CS6 software.

Analysing the sounds recorded, it was possible to find a significant correlation ($P<0.001$) between the frequencies of the vocalisations recorded and the weight of the broilers.

The results explained how the frequency of the sounds emitted by the animals was inversely proportional to the age and to the weight of the broilers; the more they grow, the lower the frequency of the sounds emitted by the animals.

This preliminary study shows how this method based on the identification of specific frequencies of the sounds, in an indoor reared broiler farm, linked to the age and to the weight of the birds, could be used as an early warning method/system to evaluate the health and welfare status of the animals at farm level, developing also an automated growth monitoring tool.

Keywords: broiler, vocalization, PLF, grow trend, frequency analysis

Introduction

The demand for meat is rapidly growing all over the world (Tullo et al., 2013) and poultry is one of the cheapest sources of animal protein. Currently, more than 40 billion chickens are produced every year by specialised industries.

Broilers are the fastest-growing farmed species and their performance is influenced by adequate environmental conditions such as ambient temperature, relative humidity, air and litter quality, and ventilation speed. Thank to the progress in farming technologies, broiler chickens now mature at a higer rate than in the past, have higher feed conversion efficiency, a reduced slaughter age and a higher final weight (Rauw et al., 1998).

Chicken weight provides information about the growth and the feed conversion efficiency of the flock useful to identify deviations from the expected homogeneous growth trend of the birds (Mollah et al., 2010), having also details about the health and welfare status of the animals.

Since the animal health strongly depends on good welfare, during the last years many progresses have been made in developing new indices/indexes and procedures to assess animal's health and welfare status. Nevertheless, these monitoring procedures are time consuming and require trained manpower (Aydin et al., 2014). For this reason, one possible way to make animal welfare assessment easier and faster could be the application of audio and video data analysis. (Tefera, 2012) (Ferrari et al., 2013; Tullo et al., 2013). Image analysis, in particular, was successfully used to estimate the body weight of the animals (Mollah et al., 2010) while audio analysis have been widely used to better identify specific behaviours and vocalisation patterns in different animals' species (Chan et al., 2011; Vandermeulen et al., 2013).

Animals use vocalisation to express different inner states provoked either by internal or external events, and also to reveal some of their behavioural needs (Aydin et al., 2014). For instance, chicken broiler vocalisations have been studied (Marx et al., 2001) to better understand the vocal pattern of this species in relation to environmental temperatures and stress situations (e.g. high/low temperatures). Moreover, information technologies have been used to monitor feed intake, body weight and growth trend (Aydin et al., 2014).

The non-invasive nature of the audio and video equipment allows its use in long term monitoring of animals, without disturbing them (Aydin et al., 2013).

The combination of audio and video information into automated tools could be used in early warning systems to detect health or welfare problems (Precision Livestock Farming-PLF) (Costa et al., 2013). One of the objectives of PLF is to develop on-line tools for monitoring farm animals continuously and automatically (Viazzi et al., 2011) during their life without imposing additional stress. The PLF approach can be applied to different aspects of management, with a focus on the animals and/or on the environment, and at different scales, from the individual to the entire flock/herd (Wathes, 2009). Moreover, PLF may also be used to aid the management of some complex biological production processes, to measure the growth rate and to monitor the animal activity (Halachmi et al., 2002; Ismayilova et al., 2013; Tullo et al., 2013).

The aim of this study was to record and analyse broiler vocalisations under normal farm conditions, to identify the relation between animal sounds and growth trends. The relation between Peak Frequency (PF) of sounds emitted by broiler chickens during the production cycle and their weights (both measured with an automated and a manual scale) were investigated. This study proves that audio and video data monitoring is a promising technique for the development of an automated growth-monitoring tool for the farming of broiler chickens.

Material and methods

Two experimental trials were carried out in an indoor reared broiler farm; the first one took placed in June and July 2013 and the second one in August and September 2013.

The farm where the experimental trials took place was an indoor broiler farm rearing birds to the RTFA (ACP) standard. The house dimensions were 61m x 21m and the total floor area available to the birds was 1,130m^2. Inside the house there were 2,340 nipples drinkers, and 385 feed pans available to birds. 27,940 day old chicks were placed inside the house at day 1 in both trials.

Sound recordings were collected using a professional handheld solid state recorder (Marantz PMD 661 MK II) which was connected to two different directional microphones placed at an intermediate height of between 0.4m and 0.8m (depending on the height of the animals in order to keep the same distance among animals and microphones during the entire data-collecting procedure).

The supercardioid/lobe microphone (Mic. 1) was a Sennheiser K6 / ME66" (frequency response: 40-20,000Hz ± 2,5 dB) and it was held by a short tripod microphone stand (Quiklok A341) above the feeder.

The (cardioid) microphone (Mic. 2) was a Sennheiser K6 / ME64" (frequency response: 40-20,000Hz ± 2,5 dB) and it was placed on a long tripod (Quiklok A492 Heavy-Duty Boom Mic Stand) directly above the drinkers.

Both the microphones were slightly inclined toward the floor in order to capture preferentially the sounds coming from the birds walking exactly in front of the microphone axis.

The recordings provided a sound image of background noise, and gave a better idea of the overall condition inside the broiler house.

The Marantz PMD 661 MK II recording machine had a large range of potential recording settings. The settings found to give the most sensitivity to bird sounds in the poultry house environment were:

Rec. Format: PCM-16, Stereo Sample Rate: 44.1k

Level Control.: Manual Low Cut: Off High Cut: Off

Animal sounds were recorded for 1 continuous hour using 2 different microphones during each experimental session from day 1 to day 38. Recordings were made at regular intervals every Monday, Wednesday and Friday, with the same position of the equipment along the trial procedures.

Once a week, 50 birds were selected at random and their weight recorded in order to follow the growth changes in the birds. Throughout the production period from day 1 to day 38 house temperature and humidity levels were recorded.

The entire data collection consisted in 16 days of sound recordings for trial 1, 15 days of sound recordings for trial 2, and 6 weekly weight collections for both trials.

In total 55 h 20 min of recordings were collected and 600 birds were weighted during trial 1 and trial 2; only the audio files recorded in conjunction with the weight collection of the birds were included in the data analysis.

In total 600 sounds (50 sounds per day), chosen at random and selected from 12 days of recordings were manually labelled and analysed in this study.

Sound analysis

Sound recordings were manually analysed and labelled using sound analysis software: Adobe® Audition™ CS6. Every hour-long duration recorded digital file was cut into shorter files of 10 minutes each in order to simplify the sound analysis.

Sound labelling involved the extraction and classification of both individual animal sounds and general sounds coming from the whole flock on the basis of the amplitude and frequency of the sound signal in audio files recorded at farm level (Tullo et al., 2013).

Labelling is a manual procedure based on acoustic analysis combined with visual spectral analysis, which is used to extract fragments of sounds from the entire recording. The labelling procedure was done offline by extrapolating those sounds that the operator classified as significant vocalisation sounds *via* auditive analysis and visual observation of the spectrogram (Ferrari et al., 2008).

Through Adobe® Audition™ CS6 each sounds were identified and analysed using time (x-axis) and frequency (y-axis).

The Fast Fourier Transform (FFT) was used to perform the frequency analyses using a Hamming window with a FFT dimension of 256 sampled points (Figure 1).

For each sound the peak frequency (PF= representing the frequency of maximum power) was manually extracted. The frequency range was band pass filtered between 1,000 Hz to 13,000 Hz. The lower frequency limit was set at 1,000 Hz to remove the low frequency background noise and the upper limit was set at 13,000 Hz to cut off the high frequency noise and also because broilers are sensitive to a frequency range of about 60 to 11,950 (Appleby et al., 1992; Tefera, 2012).

Figure 1.

Statistical analysis

Differences among PF extracted from the 600 sounds recorded in the two trials were tested with the PROC TTEST of SAS 9.3. A paired t-test was performed to compare PF of sounds recorded at different ages of birds within the same trial. The relation between weight and PF of sounds recorded at different ages was also investigated with PROC CORR in SAS 9.3.The PROC REG. was used to predict variation in the PF according to the change of age of the birds (in weeks) with the following model:

$$PF = week$$

The estimation of effects influencing the PF was performed with the GLM procedure in SAS 9.3. The model used was the following:

$$PF = weight*age$$

Table 1.

The fixed effect (weight*age) was divided in 12 classes, as the result of the interaction (pairing) of the age with the average weight of the birds (Table 1). The division in classes allowed avoiding the nesting effect.

Results and discussion

Table 2.

For each sound the frequency analysis was carried out, in order to extract the peak frequency of each vocalisation. The mean weights collected during both trials agree with the growth trend of this breed found in literature (Aviagen, 2012).

Table 3 shows the means and standard deviations of the peak frequency (PF) of sounds recorded in trial 1 and trial 2.

The comparison shown in Figure 2 shows how there is no difference (P value= 0.4508) between PF means of the sounds recorded in the two trials.

Figure 2.

Furthermore, the comparison between PF of sounds collected on the same week of age of birds during the experimental trials (Figure 3) confirmed that the two trials could be considered as the equivalent. This could be related to the use in poultry farming of fast-growing hybrid broilers with typical and homogeneous growth rate across production cycles.

Indeed all the P values reported in Fig 3 reveal the non-significant difference between PF means of the sounds emitted by the animals during specific days of both trials.

Figure 3.

In Table 3 the paired T-test between days of the same trial were tested to verify the difference between the PF means of the vocalisation during the life of the broiler chickens; the difference is resulted significant in both trials

As it is possible to see in Table 4 and Table 5 and in Figure 3 each age is characterised by its own typical peak frequency that decreases with the growth of the birds.

Considering the difference between week 1 and week 6 it is possible to see how the peak frequency decreases of about 2,000 Hz.

In both trials the average frequency reduction was around 350 Hz per week.

Furthermore analysing the PF related to the weight of birds, it was possible to confirm a significant negative correlation (-0.80; P<0.0001) between the frequencies of the vocalisations recorded and the weight of the broilers, during the different experimental trials.

Table 3.

As it is shown in Figure 4 the peak frequency of the vocalisations of the broiler chickens is strictly dependent on the age and on the weight of birds.

The regression model is significant (F=251.52, P <0.0001), indicating that the model accounts for a significant portion of variation in the data. The R^2 indicates that the model accounts for 98% of the variation in peak frequency.

The confidence interval (CI_obs_95) of the observed values shows a 95% probability that the true linear regression line of the population will lie within the confidence interval of the regression line calculated from the sample data.

The confidence interval (CI_exp_95) that includes the expected values of the regression model with a probability of 95% (grey area in Fig 4) indicates the goodness of fit of the regression model.

Figure 4.

The results of the GLM were useful to verify the high impact of the weight and the age of the birds on the PF of the vocalisation emitted by the animals during their life. In Figure 5 are reported the LSMEANS(± SEM) of the PF of vocalisations according to the increase of the age and weight of the animals.

There is a decrease of peak frequency in vocalisations according to the age of the broiler chickens.

As reported by Marx et al. (2001) the PF of the vocalisation emitted by one week old chicks ranged from 3,000 to 4,000 Hz, reinforcing the results of the present study that very young chicks vocalise at high frequency under non-stress condition.

Figure 5.

Conclusion

The results indicate that the peak frequency of the sounds emitted by the animals, is inversely proportional to the age and the weight of the broilers; specifically the more they grew, the lower the frequency of the sounds emitted by the animals.

Usually, nowadays, the weight of the birds is automatically collected by a single solid scale placed on the floor of the house. The high numbers of animals inside the flock and the insufficient funds of scales make impossible to collect the weight of all the birds. Manually measure the weight of a significant number of animals requires manpower and deprives the farmer of useful time. Due to this, it should be useful to automatically collect simultaneously information about the growth trend of all the birds inside the flock to identify deviations from the expected homogeneous growth trend of the birds, having also details about the health and welfare status of the animals.

This preliminary study shows that the methodological approach based on the identification of specific sound frequencies emitted by the animals in an indoor reared broiler farm linked to their age and weight, could be used as an early warning method/system or a continuous monitoring system to evaluate the general status of the animals at farm level. Furthermore, this strict correlation between weight of the birds and peak frequency of the sounds emitted by the animals could open the scenario to an automated tool based on vocalisation to predict the weight and the growth trend of the birds. This allow the farmer to automatically monitor the growth trend of the birds,

Of course further studies, in different farms, with daily data collection are necessary to improve the knowledge on the relationship between vocalisation and weight of birds in order to create an accurate weight prediction algorithm based on sounds emitted by the animals.

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Figure Headings:

Figure 1. Screenshot of the Adobe® Audition ™ software showing the spectrograms and the frequency analysis window relative to a specific vocalisation. In the main window the time- frequency vocalisation graph is shown, while the inset represents the frequency analysis.

Figure 2. Comparison between PF means of the sounds recorded in trial 1 and in trial 2.

Figure 3. Comparison between PF means of sounds emitted during days of the same week of age recorded in different trials.

Figure 4. Linear regression of PF in relation to the age of the animals expressed in weeks. Confidence intervals of the mean are reported in dotted lines. Confidence intervals of the prediction are represented by the grey area.

Figure 5. LSMEANS(± SEM) of the peak frequency of vocalisation according to the increase of age and weight. $P < .0001$

Tables:

Table 1. Description of the fixed effect Weight*age used in the GLM model. The 12 classes, are the result of the interaction (pairing) of the age with the average weight of the birds.

Table 2. 50 Chicken broilers randomly chosen were weighted during their entire life, both in trial 1 and trial 2. Means and standard deviations (SD) of the peak frequency (PF) of the sounds recorded in both trials.

Table 3. Paired T-test between different days to verify the difference between the PF means of the vocalisations during the entire life of the broiler chickens in trial 1.

Table 1.

Weight (g)	Age (d)	Weight*age	Weight (g)	Age (d)	Weight*age
40.72	1	1	1,039.46	22	7
44.56	1	2	1,092.84	23	8
198.64	8	3	1,529.00	29	9
231.42	9	4	1,731.60	30	10
550.30	15	5	2,104.28	36	11
608.66	16	6	2,275.44	37	12

Table 2.

Week	Trial	Day	Mean weights (g) ±SD	Mean PF (Hz) ±SD
1	1	1	44.56 ± 1.5	3,545± 365
2	1	8	198.64 ± 10.1	3,059 ±459
3	1	15	550.3 ± 21.7	2,618 ±360
4	1	22	1,039.5± 68.6	2,329 ± 605
5	1	29	1,529± 120.5	1,943 ± 569
6	1	36	2,104.28± 208.5	1,506 ±434
1	2	1	40.72 ± 4.9	3,621 ±402
2	2	8	231.42 ± 1.1	2,953 ± 353
3	2	15	608.66 ± 26.7	2,474 ± 384
4	2	22	1,092.84± 74.4	1,955 ± 520
5	2	29	1,731.6± 130.3	1,902 ± 585
6	2	36	2,275.44± 247.0	1,475 ± 493

Table 3.

Trial 1			Trial 2		
Comparison	Difference Mean (SEM)	P-value	Comparison	Difference Mean (SEM)	P-value
Day 1 – Day 8	485.8 (76.7)	***	Day 1 – Day 9	668.4 (73.4)	***
Day 1 – Day 15	926.8 (66.9)	***	Day 1 – Day 16	1,174.3 (87.69)	***
Day 1 – Day 22	1,216.2 (103.8)	***	Day 1 – Day 23	1,674.1 (121.4)	***
Day 1 – Day 29	1,602.1 (93.3)	***	Day 1 – Day 30	1,740.3 (120.7)	***
Day 1 – Day 36	2,039.6 (94.3)	***	Day 1 – Day 37	2,146.4 (80.8)	***
Day 8 – Day 15	441.0 (72.2)	***	Day 9 – Day 16	478.9 (79.4)	***
Day 8 – Day 22	730.4 (106.8)	***	Day 9 – Day 23	949.7 (96.6)	***
Day 8 – Day 29	1,116.3 (108.4)	***	Day 9 – Day 30	1,015.9 (109.0)	***
Day 8 – Day 36	1,553.8 (85.5)	***	Day 9 – Day 37	1,478.0 (80.6)	***
Day 15 – Day 22	289.4 (91.5)	***	Day 16 – Day 23	485.9 (102.2)	***
Day 15 – Day 29	675.3 (100.7)	***	Day 16 – Day 30	552.1 (107.2)	***
Day 15 – Day 36	1,112.8 (81.8)	***	Day 16 – Day 37	999.1 (97.1)	***
Day 22 – Day 29	385.9 (124.8)	**	Day 23 – Day 30	366.3 (136.4)	*
Day 22 – Day 36	823.4 (101.5)	***	Day 23 – Day 37	428.5 (137.0)	**
Day 29 – Day 36	437.6 (101.7)	***	Day 30 – Day 37	362.2 (130.6)	**